Mg II Detection in the Lyα Forest: Metal Rich Cloud or LSB Dwarf Galaxy?

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Abstract. We report the detection of Mg II absorption in two Lyα forest clouds along the line of sight to PKS 0454 + 039. These clouds, at redshifts $z = 0.6248$ and $z = 0.9315$, respectively, also have strong Fe II absorption. We present results on the $z = 0.9315$ cloud. The upper limit on $\log N$(H I) is 16.5 cm^{-2}. Based upon UV background photoionization models, we infer that the cloud has super–solar metallicity. Photoionization by a late–type stellar population is ruled out.

1 Scientific Considerations

Metal–line absorption in the intergalactic medium (IGM, i.e. Lyα forest clouds) is astrophysically interesting because the absorption properties can be exploited to reveal the chemical enrichment and ionization histories of the universe. At all redshifts, forest clouds far from bright galaxies may sample IGM chemical enrichment from the first generation of stars. At low redshifts, they may trace a population of low surface brightness and/or dwarf galaxies.

Cowie et al. [3] detected high ionization C IV and Si IV in the forest at $z \sim 2.5$, where the UV background (UVB) is likely dominated by "hard" radiation from quasars and active galactic nuclei. At $z < 1$, the UVB intensity is reduced by a factor of ~ 5 and its shape may be softened by bright field galaxies. In short, the IGM ionization conditions may have evolved so that low ionization species, i.e. Mg II and Fe II, are detectable in "forest" clouds.

2 An LSB Galaxy or Metal Enhanced Cloud?

We searched a HIRES/Keck spectrum of PKS 0454 + 039 for Mg II absorption in the Lyα clouds reported by Boissé et al. [1]. The success rate was 2/28, or $\sim 7\%$. The upper limits are $\log N$(Mg II) = 10.55–11.06 cm^{-2} for $0.11 < W_r(1215) < 10.1$ Å H I clouds. The two discovered systems, at z 0.6248 and 0.9315, have $W_r(1215) = 0.33$ and 0.15 Å, respectively. In Figure 1, the 0.93 system is presented. The unresolved metal lines were fitted with Voigt profiles and extensive Monte Carlo simulations were performed to obtain the column densities and b parameters. We obtained $12.3 < \log N < 12.6$ cm^{-2} for both Mg II and Fe II, with $1.4 < b < 2.2$ km s^{-1}. We assumed the cloud is thermally broadened and used the curve of growth to estimate $14.2 <$

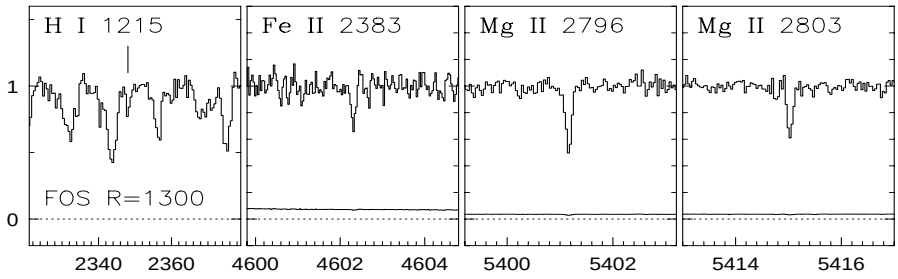

Figure 1: The FOS/HST and HIRES/Keck (metal lines) spectra of the $z = 0.93$ cloud. The tick marks the Lyα λ1215 absorption line. Only upper limits are found for C II, C III, C IV, Si IV, N V, and O VI.

$\log N(\text{H I}) < 16.5$ cm^{-2}. We then used CLOUDY [4], once with a $\nu^{-1.5}$ UV continuum slope and once with $T \approx 5000$ K blackbody spectrum [cool stars are suggested by $N(\text{Fe II})/N(\text{Mg II}) \sim 1$], to explore the cloud chemical and ionization conditions.

For the power–law UVB with $J_{-21} = 0.2$, the cloud properties are $n_H \sim 0.05$ cm^{-3}, $D \sim 5$ pc, and $M \sim 10^{-3}$ M$_\odot$, with ionization parameter $\log U \sim -3.5$. This cloud is inferred to have super–solar metallicity, $0.5 < [Z/Z_\odot] < 1.5$! In a F702W WFPC/HST image of the $0454+039$ field [5] there are a few diffuse extended LSB galaxies over the impact parameter range $20 < Dh^{-1} < 60$ kpc, if they have $z = 0.93$. However, it is difficult to understand how extended super–solar gas could arise from such diffuse galaxies.

For the blackbody "cool stars" UV continuum, the inferred cloud properties are $n_H \sim 0.1$ cm^{-3}, $D \sim 100$ pc, and $M \sim 600$ M$_\odot$, with $\log U \sim +1$. The inferred metallicity is $[Z/Z_\odot] \sim -1.2$. This scenario models a dwarf–like galaxy with a late–type stellar population. The value of U implies an extreme number of stars; this scenario is astrophysically implausible [2]. We thus conclude that the absorber is metal rich and ionized by the UVB.

It may be that systems like the one presented here are fairly common and comprise a yet–to–be explored class of absorber. A sensitive search for Mg II systems in the forests along the lines of sight to other QSOs is in progress.

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